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(54) **Device for purifying exhaust gas of diesel engines**

(57) A device for purifying exhaust gas of diesel engines (10), in which an oxidizing catalyst (20), a diesel particulate filter (21), and an NOx occluding/reducing catalyst (22) are successively disposed in an exhaust gas passage (13) of the diesel engine (10) from the upstream side of the passage, the device for purifying exhaust gas of diesel engines (10) comprising a bypass (15) that connects the upstream side of the oxidizing catalyst (20) with the downstream side thereof in the exhaust gas passage (13), an exhaust gas passage change-over means (32, 34) for changing-over the exhaust gas flow into either the oxidizing catalyst (20) or the bypass (15), an air-fuel ratio control means (30) for

controlling the air-fuel ratio of the exhaust gas, an NOx occlusion amount detector means (40d) for detecting the amount of NOx occluded by the NOx occluding substance, and a controller (40). The controller (40) controls the air-fuel ratio control means (30) and the exhaust gas passage change-over means (32, 34) so that the exhaust gas having a lean air-fuel ratio flows into the oxidizing catalyst (20) when the amount of NOx occluded by the NOx occluding substance does not reach a predetermined value, and so that the exhaust gas having a rich air-fuel ratio flows through the bypass (15) when the amount of NOx occluded by the NOx occluding substance exceeds the predetermined value.

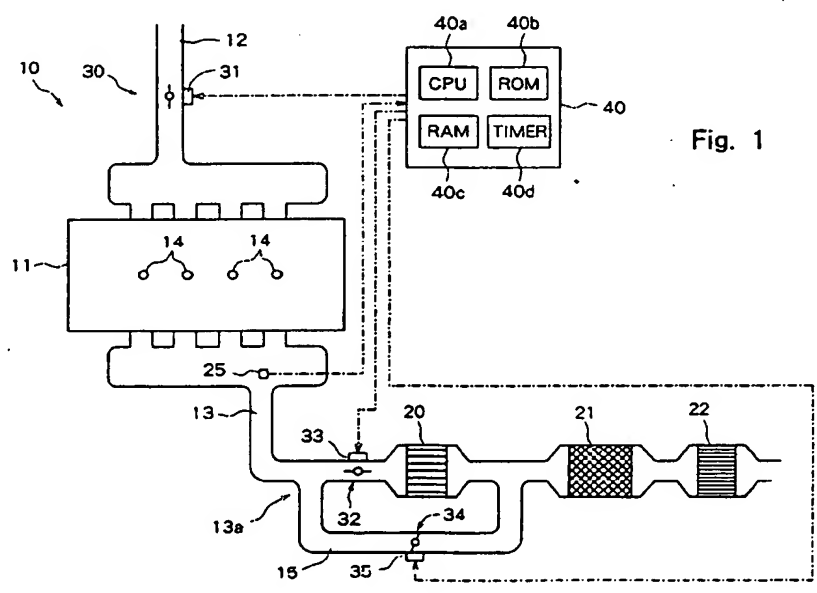


Fig. 1

and with an NOx occluding/reducing catalyst.

[0009] In order to accomplish the above-mentioned object according to the present invention, there is provided a device for purifying exhaust gas of diesel engines, in which an oxidizing catalyst, a diesel particulate filter for trapping particulate matters contained in the exhaust gas, and an NOx occluding/reducing catalyst comprising an NOx occluding substance and a catalytically active component, are successively arranged in an exhaust gas passage of the diesel engine from the upstream side of the passage, said device for purifying exhaust gas of diesel engines comprising:

a bypass that connects the upstream side of said oxidizing catalyst with the downstream side thereof in said exhaust gas passage to bypass said oxidizing catalyst;

an exhaust gas passage change-over means for changing-over the exhaust gas flow to either said oxidizing catalyst or said bypass;

an air-fuel ratio control means for controlling the air-fuel ratio of the exhaust gas;

an NOx occlusion amount detector means for detecting the amount of NOx occluded by said NOx occluding substance; and

a controller for controlling said air-fuel ratio control means and said exhaust gas passage change-over means based on a detection signal from said NOx occlusion amount detector means;

wherein said controller controls said air-fuel ratio control means so that the exhaust gas will have a lean air-fuel ratio and controls said exhaust gas passage change-over means so that the exhaust gas will flow through said oxidizing catalyst when the amount of NOx occluded by said NOx occluding substance does not reach a predetermined value, and controls said air-fuel ratio control means so that the exhaust gas will have a rich air-fuel ratio and controls said exhaust gas passage change-over means so that the exhaust gas will flow through said bypass when the amount of NOx occluded by said NOx occluding substance exceeds the predetermined value.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Fig. 1 is a diagram illustrating the constitution of a device for purifying exhaust gas of diesel engines according to an embodiment of the present invention;

Fig. 2 is a flowchart of a routine executed by a controller for determining the opening angle of an intake air throttle valve and for determining the opening/closing of an exhaust gas passage opening/closing valve and of a bypass opening/closing valve; and Fig. 3 is a diagram schematically illustrating (a) an

NOx occluding mechanism of when the exhaust gas has a lean air-fuel ratio and (b) an NOx reducing mechanism of when the exhaust gas has a rich air-fuel ratio in the NOx occluding/reducing catalyst.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] An embodiment of the invention will now be described with reference to the drawings.

[0012] Fig. 1 is a diagram illustrating the constitution of a device for purifying exhaust gas of diesel engines according to an embodiment of the present invention. A diesel engine 10 in Fig. 1 comprises an engine body 11 constituted by a cylinder block and a cylinder head, an intake air passage 12 for introducing the air into the cylinders formed in the engine body 11, and an exhaust gas passage 13 for emitting the exhaust gas from the cylinders of the engine body 11. In the engine body 11 are disposed fuel injection nozzles 14 for injecting fuel into the combustion chambers that are not shown.

[0013] In the exhaust gas passage 13, there are successively disposed an oxidizing catalyst 20, a DPF 21 and an NOx occluding/reducing catalyst 22 from the upstream side thereof. These devices will now be described in detail.

[0014] The oxidizing catalyst 20 is obtained by coating the surfaces of a carrier of, for example, honeycomb-like cordierite or a heat-resistant steel with active alumina to form a wash coat layer, and carrying a catalytically active component which is a novel metal such as platinum, palladium or rhodium on the wash coat layer. When the exhaust gas is passed through the thus constituted oxidizing catalyst 20, the NO in the exhaust gas is oxidized to form NO<sub>2</sub> when the exhaust gas has a lean air-fuel ratio, but is not oxidized when the exhaust gas has a rich air-fuel ratio. The HC and CO in the exhaust gas are oxidized to form H<sub>2</sub>O and CO<sub>2</sub> in both the cases where the exhaust gas has a lean air-fuel ratio or a rich air-fuel ratio.

[0015] In this specification, the air-fuel ratio of the exhaust gas represents a ratio of the amount of air in the exhaust gas flowing through the exhaust gas passage 13 to the amount of fuel (hydrocarbons) therein. If neither the air nor the fuel is newly supplied to the exhaust gas emitted by the combustion in the combustion chambers of the engine body 11, the air-fuel ratio of the exhaust gas becomes equal to a ratio of the amount of the air taken in by the cylinders in the engine body 11 to the amount of fuel injected from the fuel injection nozzles 14. Therefore, the exhaust gas having an air-fuel ratio (e.g., air-fuel ratio of 30) leaner than the stoichiometric air-fuel ratio acquires an increased oxygen concentration to create an oxidizing atmosphere. Conversely, the exhaust gas having an air-fuel ratio (e.g., air-fuel ratio of 13) richer than the stoichiometric air-fuel ratio acquires increased HC and CO concentrations to create a reducing atmosphere.

described later.

[0021] In the intake air passage 12 is disposed an intake air throttle valve 30 which adjusts an amount of the air taken in into the cylinders formed in the engine body 11. The opening angle of the intake air throttle valve 30 is adjusted by an actuator 31 of the negative pressure type. The actuator 31 adjusts the opening angle of the intake air throttle valve 30 by adjusting the proportion of negative pressure introduced into the negative pressure chamber from a vacuum pump that is not shown. By disposing the intake air throttle valve 30 in the intake air passage 12 as described above, it becomes possible to control the air-fuel ratio of the exhaust gas. That is, when the intake air throttle valve 30 is fully opened, the combustion takes place in the combustion chambers of the engine body 11 in an air (oxygen)-rich atmosphere under ordinary diesel combustion conditions, and the air-fuel ratio of the exhaust gas becomes lean (e.g., air-fuel ratio of 30). When the intake air throttle valve 30 is narrowed down, on the other hand, an amount of the air taken in into the cylinders of the engine body 11 decreases, whereby the combustion takes place in the combustion chambers in an air-deficient state and the air-fuel ratio of the exhaust gas becomes rich (e.g., air-fuel ratio of 13 when the opening angle of the intake air throttle valve 30 is 1/10). According to the illustrated embodiment as described above, the intake air throttle valve 30 works as an air-fuel ratio control means for controlling the air-fuel ratio of the exhaust gas.

[0022] Further, the intake air throttle valve 30 is also capable of controlling the temperature of the exhaust gas. That is, when the intake air throttle valve 30 is narrowed down, a decreased amount of the air is taken in into the cylinders of the engine body 11, and the temperature of the exhaust gas rises. The temperature to be raised is controlled in compliance with the opening angle of the intake air throttle valve 30. Thus, by narrowing the intake air throttle valve 30 down as described above, the air-fuel ratio of the exhaust gas can be enriched and the temperature of the exhaust gas can be further raised. Here, if the intake air throttle valve 30 is narrowed down in a range in which the air-fuel ratio of the exhaust gas does not become rich (e.g., the air-fuel ratio becomes from 20 to 30 when the intake air throttle valve 30 is opened by 1/2 to full throttle), the temperature of the exhaust gas can be raised while keeping the air-fuel ratio of the exhaust gas lean.

[0023] The device for purifying exhaust gas of the diesel engine 10 has a controller 40 for controlling the intake air throttle valve 30, the exhaust gas passage opening/closing valve 32 and the bypass opening/closing valve 34. The controller 40 comprises a central processing unit (CPU) 40a for executing a variety of operation programs, a read-only memory (ROM) 40b storing a variety of operation programs to be executed by the CPU 40a and map data, a random access memory (RAM) 40c for temporarily storing the results operated by the CPU 40a and data received from the sensors, and a timer

40d (T) for counting the time. The controller makes a reference to the exhaust gas temperature detected by an exhaust gas temperature sensor 25, sends a control signal to the actuator 31 of the intake air throttle valve 30 and adjusts the opening angle of the intake air throttle valve 30 to control the air-fuel ratio and the temperature of the exhaust gas. The controller 40 further sends control signals to the actuators 33, 35 of the exhaust gas passage opening/closing valve 32 and of the bypass opening/closing valve 34 that work as exhaust gas passage change-over means, and opens and closes the exhaust gas passage opening/closing valve 32 and the bypass opening/closing valve 34, so that the exhaust gas flows through either one of the oxidizing catalyst 20 or the bypass 15.

[0024] The device for purifying exhaust gas of the diesel engines according to the illustrated embodiment is constituted as described above. Namely, the controller 40 controls the air-fuel ratio and temperature of the exhaust gas emitted from the cylinders of the engine body 11 and, further, controls the exhaust gas flow passage in the exhaust gas passage 13 to remove the PMs as well as the NOx in the exhaust gas simultaneously. Described below with reference to Fig. 2 are the control operation by the controller 40 and a process in which the exhaust gas is purified by the control operation.

[0025] Fig. 2 is a flowchart of a routine executed by the controller 40 for determining the opening angle of the intake air throttle valve 30 and for determining the opening/closing of the exhaust gas passage opening/closing valve 32 and of the bypass opening/closing valve 34. The routine of Fig. 2 has been stored in advance in the ROM 40b, and is repetitively executed by the CPU 40a at regular time intervals.

[0026] As the diesel engine 10 starts operating and the CPU 40a starts in the routine of Fig. 2, the timer 40d (T) is set to a predetermined time T1 at step S11. The predetermined time T1 is a period of time until the amount of NOx reaches a maximum amount of NOx that can be occluded by the NOx occluding substance 22b, and is set to be from about 1 to about 2 minutes in the case of a diesel engine 10 having a displacement of, for example, 3000 cc. Therefore, a means that counts the passage of time from when the predetermined time T1 has been set works as an NOx occlusion amount detector means for detecting the amount of NOx occluded by the NOx occluding substance 22b.

[0027] When the timer 40d (T) is set to the predetermined time T1 at step S11, the controller 40 judges whether the passage of time (TS) after it has been set has reached the predetermined time T1. Immediately after the start of the diesel engine 10, the predetermined period of time T1 has not been reached. Therefore, the controller 40 proceeds to step S13 to judge whether the exhaust gas temperature detected by the exhaust gas temperature sensor 25 has exceeded 250°C. When it is judged that the exhaust gas temperature has exceeded 250°C, the controller 40 proceeds to step S14. At step

controller 40 sets the timer 40d (T) to a predetermined time T2. The predetermined time T2 is the one required for releasing the NOx occluded by the NOx occluding substance 22b and reducing the NOx, and is set to be from about 0.1 to about 0.3 seconds when the diesel engine has a displacement of, for example, 3000 cc. After the timer 40d (T) is set to the predetermined time T2 at step S18, the controller 40 proceeds to step S19 to judge whether the passage of time (TS) has reached the predetermined time T2 from when the predetermined time T2 has been set. When the passage of time (TS) has not yet reached the predetermined time T2, the controller 40 executes the operation of step S19 again.

[0035] So far as it is judged at step S19 that the passage of time (TS) does not yet reach the predetermined time T2 after the predetermined time T2 has been set as described above, the exhaust gas having a rich air-fuel ratio flows into the exhaust gas passage 13 to pass through the bypass 15, DPF 2 and NOx occluding/reducing catalyst 22 in this order. Described below is the process for purifying the exhaust gas that flows as described above. As the exhaust gas passes through the bypass 15 and then, through the DPF 21, the PMs in the exhaust gas are trapped by the DPF 21. Though, when the opening angle of the intake air throttle valve 30 is narrowed down to 1/10 to enrich the air-fuel ratio of the exhaust gas, the fuel does not completely burn in the combustion chambers of the engine body 11 due to the lack of air and black smoke increases in the exhaust gas, the black smoke is removed by the DPF 21. Then, as the exhaust gas passes through the NOx occluding/reducing catalyst 22, the NOx occluded by the NOx occluding substance 22b is released therefrom and is reduced into N<sub>2</sub> with HC and CO which serve as reducing agents, in the exhaust gas. While the NOx is reduced, the HC and CO are oxidized into H<sub>2</sub>O and CO<sub>2</sub> simultaneously.

[0036] Thus, in the illustrated embodiment, when the NOx is reduced in the NOx occluding/reducing catalyst 22 by enriching the air-fuel ratio of the exhaust gas, the exhaust gas is not supplied into the oxidizing catalyst 20 but is supplied into the bypass 15. Therefore, the HC and CO in the exhaust gas that serve as reducing agents at the time of reducing the NOx released from the NOx occluding substance 22b, flow into the NOx occluding/reducing catalyst 22 without being oxidized into H<sub>2</sub>O and CO<sub>2</sub> in the oxidizing catalyst 20. Accordingly, since the NOx released from the NOx occluding substance 22b is reduced to N<sub>2</sub> with HC and CO, the NOx is not emitted into the atmosphere without being reduced.

[0037] Here, the exhaust gas having a rich air-fuel ratio does not flow through the oxidizing catalyst 20 and hence, the NO in the exhaust gas is not oxidized into NO<sub>2</sub>. Therefore, the PMs trapped by the DPF 21 accumulate thereon without being burned. As described above, however, the time until the NOx occluded by the NOx occluding substance 22b is released and is reduced is very shorter, i.e., the predetermined time T2 is

very shorter than the time until the amount of NOx occluded by the NOx occluding substance 22b reaches its maximum amount of occlusion, i.e., very shorter than the predetermined time T1. Therefore, the PMs not burned are burned when the exhaust gas is leaned again so as to have a lean air-fuel ratio and is permitted to flow through the oxidizing catalyst 20.

[0038] As the routine of step S17 through step S19 are repetitively executed as described above, the amount of NOx occluded by the NOx occluding substance 22b gradually decreases and, finally, almost no NOx exists in the NOx occluding substance 22b. Here, there exists a proportional relationship between the amount of NOx that is released from the NOx occluding substance 22b and reduced and the operation time of the diesel engine 10, like when the NOx is occluded. In the illustrated embodiment, therefore, it is so judged that the NOx occluded by the NOx occluding substance 22b is all released and reduced when the predetermined time T2 has passed from the start of release and reduction of NOx from the NOx occluding substance 22b. When it is judged at step S19 that the predetermined period T2 has passed, the controller 40 ends the routine to terminate the operation for releasing and reducing the NOx from the NOx occluding substance 22b. The controller 40, then, starts again the routine from step S11 and the NOx occluding substance 22b starts occluding the NOx.

[0039] The intake air throttle valve 30 is used not only for controlling the air-fuel ratio and the temperature of the exhaust gas but also for stopping the diesel engine 10 in combination with, for example, the fuel injection device that is not shown. Further, the exhaust gas passage opening/closing valve 32, too, can be used not only for changing over the flow of the exhaust gas but also, upon making a structure to allow continuously controlling the opening angle of the valve, for example, for promoting the warming-up at the cold start of the diesel engine 10, or as an exhaust gas brake.

[0040] In the foregoing is described the present invention based on the illustrated embodiment to which only, however, the invention is in no way limited. For example, the air-fuel ratio of the exhaust gas may be controlled by a so-called post injection in which a very small amount of fuel is injected into the combustion chambers in the latter half of the combustion stroke (e.g., near 60° after the compression top dead center) or by the EGR. Further, the exhaust gas passage change-over means may be constituted by a three-way valve provided in a portion (13a in Fig. 1) where the bypass is connected to the upstream side of the oxidizing catalyst to selectively change the flow of the exhaust gas to either the oxidizing catalyst or the bypass. Further, as the NOx occlusion amount detector means for detecting the amount of NOx occluded by the NOx occluding substance, there may be used a fuel injection amount integrating means for integrating the amount of fuel injected into the combustion chambers, or an NOx sensor may be disposed in

**Fig. 1**

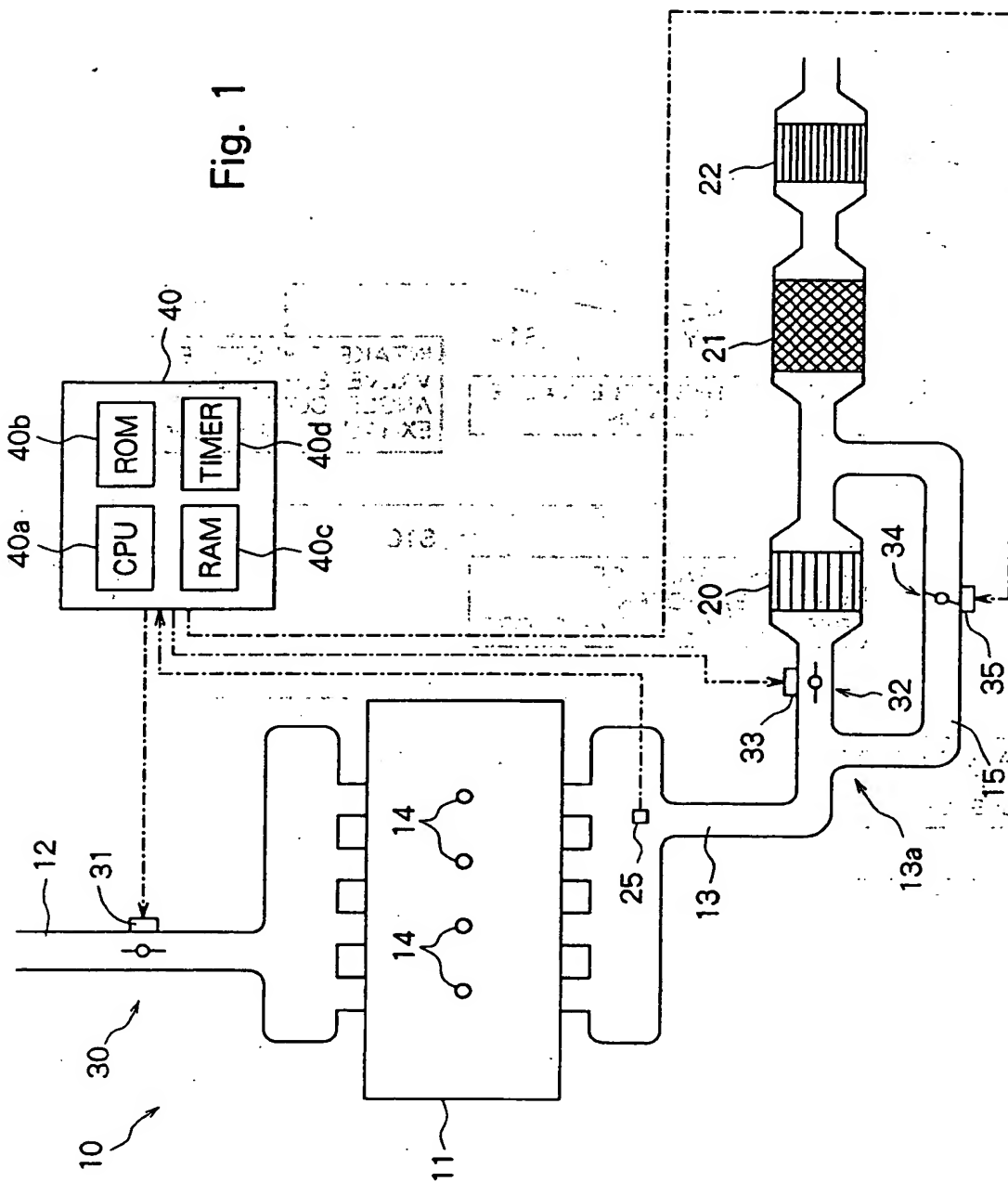
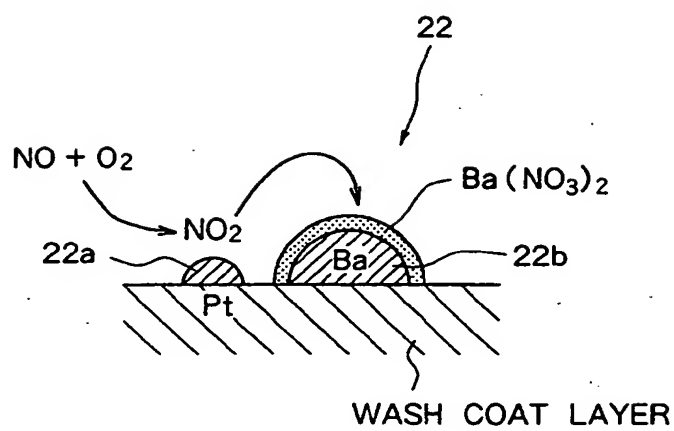


Fig. 3

(a)



(b)

